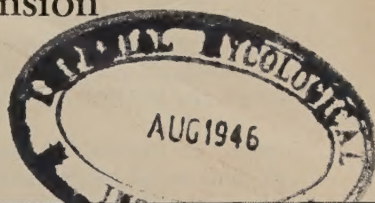


Tipburn of Lettuce

Effect of Maturity, Air and Soil Temperature
and Soil Moisture Tension

E. M. Andersen



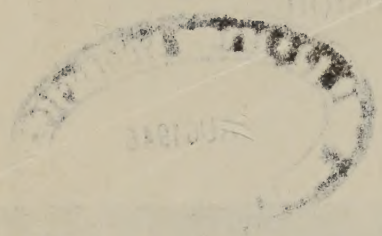
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Tribunal of Justice

Effect of Maritime, Air and Soil Temperature
and Soil Moisture on the Growth of Plants

By J. H. ...



9 JUL 1948

P.A.B

TIPBURN OF LETTUCE

EFFECT OF MATURITY, AIR AND SOIL TEMPERATURE AND SOIL MOISTURE TENSION¹

E. M. ANDERSEN²

Tipburn of lettuce is a physiological breakdown of the outer internal head leaves and inner wrapper leaves of head lettuce which annually causes large losses to lettuce growers. It may also affect leaf lettuce but rarely does severe damage.

Because of its economic importance, a considerable amount of experimental work has been done on tipburn. Most investigators agree that the trouble is most likely to occur when the head approaches marketable size and many believe that plants that have made rapid succulent growth are more susceptible to it than are plants that have made a slower growth. With the exception of those observations, conclusions as to cause are most divergent. Newhall (1929) concluded that tipburn was caused by high temperatures. The injury in the field was always most severe if a hot period were preceded by a cool moist period. He felt that high soil moisture increased tipburn but that inability to separate the growth rate from the soil moisture factor made it impossible to place the responsibility for tipburn solely on the high soil moisture.

Schmidt (1930, 1931) found no correlation between maximum air temperature and tipburn. He found that tipburn was more severe in plots with higher moisture content. Similar results were reported by Schwalen and Wharton (1930), Rawlins and McClain (1925) and Thompson (1926). Thompson was of the opinion that tipburn was due to excessive accumulation of respiratory products. He found that loss of water through rapid transpiration was not the cause of tipburn. For a bibliography of work done to 1926, consult Thompson (1926).

MATERIALS AND METHODS

Various preliminary experiments were conducted on woody peat soils of several types before two plots were selected for the experiments herein reported. These plots were located on the farms of H. F. Crumb, Whitaker Road, and Harry Fitch, Ingalls Crossing, both near Fulton, New York. Growers in the area had long considered the Crumb peat a "dry muck" and the Fitch peat a "wet muck".

The peat at the Crumb plot was a uniform, well-decomposed woody type, about 10 feet deep, which had been under cultivation for 24 years. The surface 30 inches was a dark brownish-black mixture of fine granular

¹Paper No. 277 Department of Vegetable Crops. Condensed from a thesis presented to the Graduate School of Cornell University in partial fulfillment of the requirements for the degree of Doctor of Philosophy. Those interested in more complete data may borrow a copy of the thesis from the Cornell University Library.

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material. A more fibrous light brown layer of less decomposed peat underlaid the surface layer. Shallow, empty drainage ditches ran along the north and south sides of the experimental bed. In a main drainage ditch across the west end of the rows, water flowed throughout the season at a depth of 22 inches below the surface of the bed.

The peat at the Fitch plot was a uniform but less decomposed woody type about 4 to 5 feet deep which had been under cultivation for 19 years. The surface 8 inches was a brownish-black mixture of fine granular material. A very dark brown layer of granular peat extended to a depth of 26 to 30 inches. A light brown less decomposed peat extended to a depth of 4 to 5 feet and was underlaid by 2 to 3 feet of quicksand. A drainage ditch extended across the west end of the plot. Water flowed in it at a depth of 24 inches below the bed's surface throughout the season.

In order to obtain plants throughout the season for tipburn observations, plantings of five rows of the Imperial 44 variety of Iceberg-type lettuce were made on April 27, 1939 at each plot and at weekly intervals thereafter until June 22. The ninth (June 22) planting at the Crumb plot was burned off by drying winds and was reseeded on July 1. A tenth planting was made at the Fitch plot on July 1. Rows were 75 feet long and 18 inches apart. The five-row plantings were not replicated. Each head harvested was considered to be a unit replication in the calculation of the statistical significance of the data. It was believed that any important relationship between tipburn and physiological or environmental factors would be discovered by calculation of the correlation of severity of tipburn in individual heads with each of these factors.

A soil moisture tensiometer was placed in the center of each planting, midway between rows 3 and 4. The base of the 2½ inch porous clay cup was set at a depth of 6 inches. An official weather bureau rain gauge, air thermograph, and soil thermograph were placed nearby. A covered water table hole was located in each planting in the center row 15 feet from the tensiometer and 25 feet from the west ditch. Tension and water-table measurements were taken regularly at biweekly periods; Sunday evening, Monday morning, and Monday evening; Wednesday evening, Thursday morning and Thursday evening. Measurements were made at hourly intervals during certain 24-hour periods. Determinations of percentage of soil moisture were made periodically. Air temperature was continuously recorded in one location on each of the two plots at a level of 6 inches above the soil. Soil temperature was continuously recorded in one location at each of the two plots at a depth of 3 inches. Weekly maximum and minimum air and soil temperatures were also measured by means of a maximum-minimum thermometer kept at each thermograph location.

Lettuce plant temperatures were obtained with a Leeds-Northrup (1938) portable thermocouple outfit having an automatic zero degrees centigrade reference junction. The ends of the copper-constantin thermocouples were drawn through thin bamboo stems for a distance of about 6 inches in order to facilitate putting them into lettuce heads. A Weston (1938) light meter, model 622, was used to measure light intensity during some of the 1939 temperature studies.

Capillary soil-moisture tensiometers of the type which were used in this study were described by Richards, Russell, and Neal (1937, Figure C). Richards and Gardner (1936), and Richards, Russell, and Neal (1937)

described field operation with such tensiometers. Each tensiometer used in the present study consisted, essentially, of a porous ceramic cup connected by a rigid, copper, water-containing tube to a glass mercury manometer.

Soil moisture tensiometers show directly the physical tension under which water is held in the soil. The drier the soil, the higher the tension. There is, therefore, an inverse relationship between tensiometer readings and availability of soil moisture. The range of moisture tension for which tensiometers can be used is slightly less than one atmosphere, but as Richards and Gardner (1936), and Bradfield and Jamison (1938) pointed out, the major portion of soil moisture suitable for plant growth lies within this range. Jamison (1941, 1942) using the methods of Bradfield and Jamison (1938), determined the water holding capacity of both the Crumb and Fitch plots at various tensions. As indicated by Jamison, at pF 3.0, which is approximately one atmosphere of tension, both the Crumb and the Fitch peats contained about 100 per cent moisture on a dry-weight basis. At that pF, both peats contained about 35 per cent moisture on a volume basis. However, on both a dry weight per cent basis and a volume per cent basis, the Crumb peat contained slightly more water than the Fitch peat at lower moisture tensions. Jamison showed that a greater proportion of pores in the Fitch peat were of larger size (pF 0 to 2.0, or pore diameter greater than 30 microns) than in the Crumb peat.

STATISTICAL METHODS

The standard deviation (s), the coefficient of correlation (r), the coefficient of regression (b), and the regression equation were used in calculation of the significance of the data presented. Formulae of Wallace and Snedecor (1931) were followed in calculation of these statistical values.

RATINGS OF HEAD CLOSURE, AGE OF LEAF, AND TIPBURN SEVERITY

In order to have a scale of values for degree of maturity, age of leaf, and amount of tipburn, the following arbitrary ratings were used:

Head Closure Ratings

1. Leaves lying entirely parallel to the ground, no head.
3. Leaves folding in, definite beginning of a small head.
5. Leaves folded in, small head loosely filled with leaves.
7. Soft head, well filled with leaves.
9. Hard head, best solid marketable stage.
10. Definite seed stalk elongating inside head.

Head closures 3 to 9 are illustrated in figure 1.

"Age" of Leaf Ratings

1. Youngest leaves, under 1 inch in diameter. No chlorophyll.
3. Leaves 1 inch to 2 inches in diameter. No chlorophyll.
5. The larger, tightly folded-in head leaves. Usually no chlorophyll.
7. The head wrapper leaves. Only partly devoid of chlorophyll.
9. The frame leaves. Large green horizontal leaves.

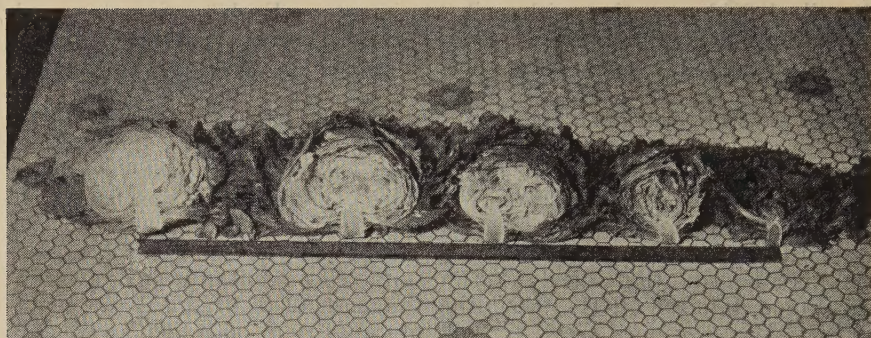


FIGURE 1. HEAD CLOSURE RATINGS, 5 SECTIONED HEADS.

Readings from left to right, 1, closure 19; 2, closure 8; 3, closure 6.5; 4, closure 4.5-5.0; and 5 closure 3.

Tipburn Severity Ratings

Complete breakdown of a strip of tissue near the apex of each of several outer leaves of the head (age 5 - 7 leaves) is the symptom of tipburn most commonly noticed. It is a late stage in the development of tipburn. The appearance of small translucent spots near the edge of the leaf is a first symptom.

1. Very slight spotting in 1 or 2 age 5 to 7 leaves.
3. Slight spotting in 2 or 3 age 5 to 7 leaves.
5. Slight spotting in most age 5 to 7 leaves.
7. Spotting in most age 5 to 7 leaves, plus some slime.
9. Spotting in large age 3 leaves as well as in age 5 to 7 leaves, plus much slime.

Figure 2 shows a head of lettuce with wrapper leaves removed to show the tipburn on age 5 leaves.

RESULTS

THE EFFECT OF RAIN AND OF CROP GROWTH ON SOIL MOISTURE TENSION

The effect of rainfall on moisture tension was very marked. The water table was only slightly affected by moderate rainfall when the soil was dry. During such periods, tensions dropped during the night where lettuce had been cut for some time or where the plants were just starting to form heads. They usually stayed high overnight where lettuce had just been cut, or where heads were rapidly maturing. The diurnal fluctuations noted during a dry period were not noted following heavy rainfall.

Average soil moisture tension and the amount of rainfall for the Fitch plot are shown in figure 3. Soil moisture tension behavior for the same plot during a dry and during a wet period are shown in figures 4 and 5, respectively. Similar data for the Crumb plot have been published (Andersen, 1939).



FIGURE 2. TIPBURN SEVERITY RATING 9.

The wilting and discoloration of tissue between the tipburn spots in the center of the photograph occurs just before the slimy stage. Note that the very edge of each affected leaf seems quite free of breakdown and that there is no breakdown at the hydathodes.

THE EFFECT OF HEAD CLOSURE AND AGE OF PLANTS ON TIPBURN

As has been commonly observed, tipburn was more severe in heads approaching or of marketable size than in those less mature. The severity of tipburn increased progressively from practically none in plants with head closure rating 5 to a tipburn severity rating of 5 in heads with closure ratings of 10. In general, head closure correlates closely with age of plants. The effect of head closure and of age of plants are shown in figures 6 and 7,

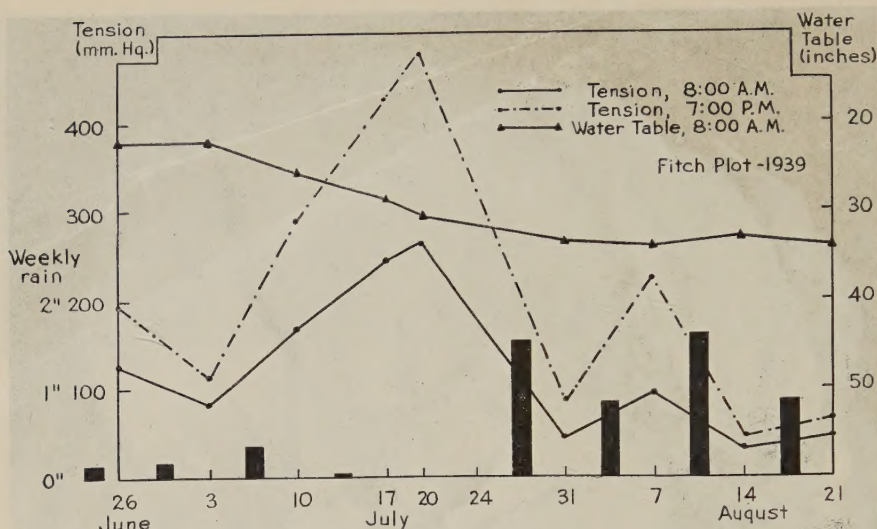


FIGURE 3. TOTAL WEEKLY RAINFALL, THE AVERAGE SOIL MOISTURE TENSION, AND THE AVERAGE WATER TABLE OF THE TEN PLANTINGS OF THE FITCH EXPERIMENT, ON THE DATES INDICATED.

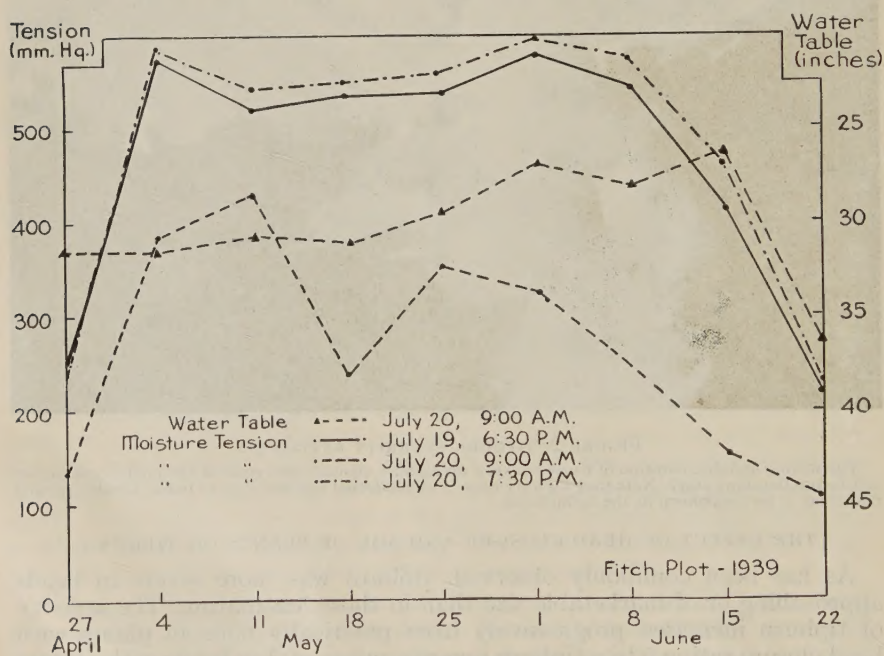


FIGURE 4. SOIL MOISTURE TENSION READINGS AND WATER TABLE MEASUREMENTS UNDER LETTUCE OF DIFFERENT PLANTING DATES DURING A DRY PERIOD, JULY 19-20, 1939. FITCH PLOT.

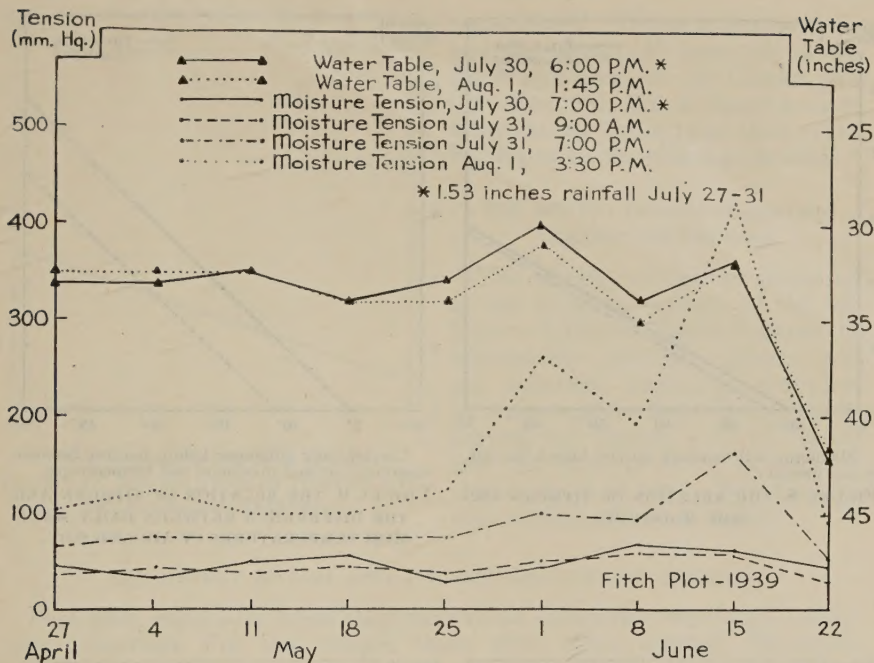


FIGURE 5. SOIL MOISTURE TENSION READINGS AND WATER TABLE MEASUREMENTS UNDER LETTUCE OF DIFFERENT PLANTINGS DURING A WET PERIOD. JULY 30-AUGUST 1, 1939. FITCH PLOT.

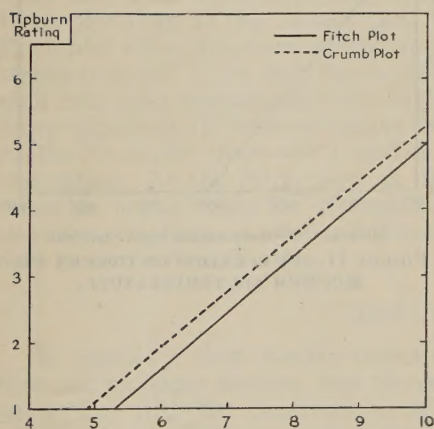


FIGURE 6. THE RELATION OF TIPBURN AND HEAD CLOSURE.

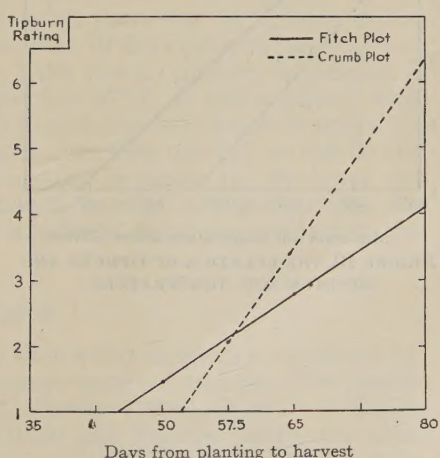
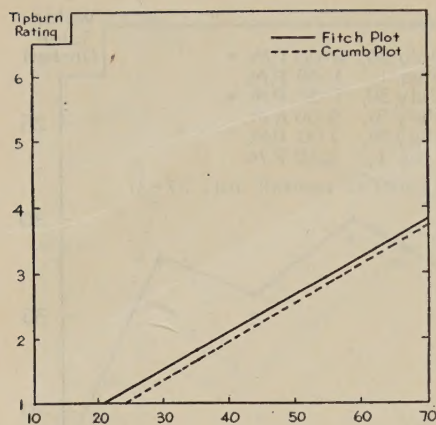
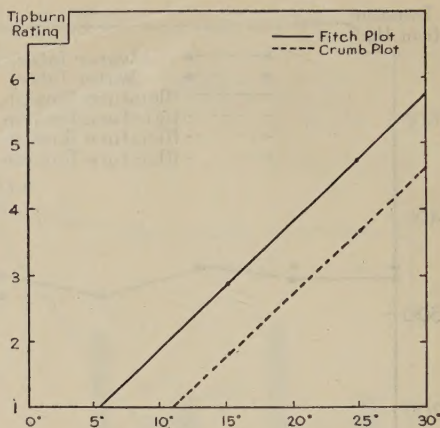


FIGURE 7. THE RELATION OF TIPBURN AND AGE OF PLANTS.



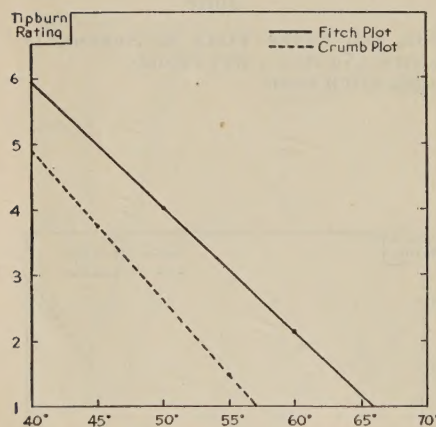
Maximum soil moisture tension before harvest, in cm. mercury

FIGURE 8. THE RELATION OF TIPBURN AND SOIL MOISTURE.



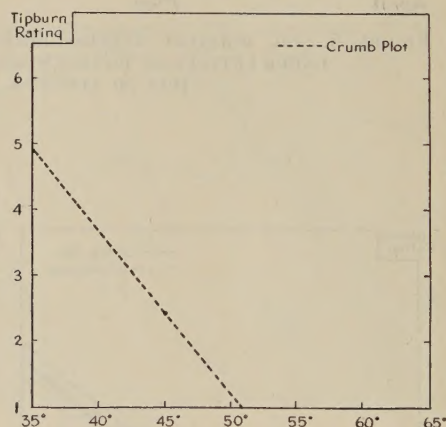
Largest daily difference before harvest between maximum air and maximum soil temperatures.

FIGURE 9. THE RELATION OF TIPBURN AND THE DIFFERENCE BETWEEN DAILY MAXIMUM TEMPERATURES OF AIR AND SOIL.



Minimum soil temperature before harvest

FIGURE 10. THE RELATION OF TIPBURN AND MINIMUM SOIL TEMPERATURE.



Minimum air temperature before harvest

FIGURE 11. THE RELATION OF TIPBURN AND MINIMUM AIR TEMPERATURE.

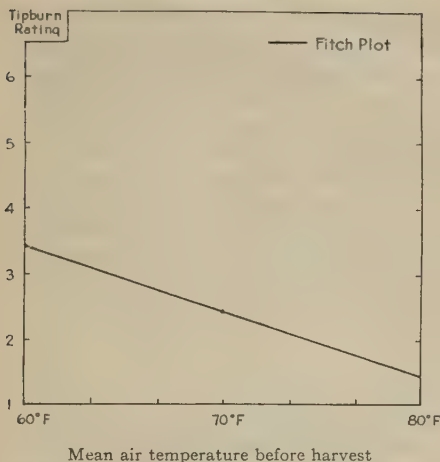


FIGURE 12. THE RELATION OF TIPBURN AND MEAN AIR TEMPERATURE.

respectively. Tipburn occurred in younger plants (45 days old) at the Fitch plot than at the Crumb plot (52 days old), but it became more severe at the Crumb plot than at the Fitch plot as the plants grew older.

THE EFFECT OF SOIL MOISTURE TENSION ON TIPBURN

The severity of tipburn increased as the moisture content of the soil became depleted. Figure 8 shows the relationship between tipburn and soil moisture tension as indicated by tensiometers five days prior to harvest for closure 4 to 5.5 heads and ten days prior to harvest for closure 6 to 10 heads. Results were very similar on the two plots.

THE EFFECT OF SOIL AND AIR TEMPERATURE ON TIPBURN

Peat soils, especially when they have dried somewhat, have high insulatory properties. For that reason there were often marked differences between the air temperature and the soil temperature. When the differences between the maximum soil temperature and the maximum air temperature increased five days prior to harvest for closure 4 to 5.5 heads and ten days prior to harvest for closure 6 to 10 heads, the severity of tipburn increased as shown in figure 9.

Tipburn also increased with lower soil temperatures on both plots as indicated by figure 10.

At the same minimum temperature, there was more tipburn at the Fitch plot than at the Crumb plot. Usually, there was no tipburn at the Fitch plot when minimum temperature, 5 to 10 days prior to harvest, was higher than 65° F. At the Crumb plot, there was no tipburn, in general, if such minimum temperature were higher than 57° F. It also increased with lower minimum air temperatures at the Crumb plot as is shown in figure 11. At the Fitch plot there was a tendency in that direction but no significant correlation. At the Fitch plot, as illustrated in figure 12, the lower the mean air temperature for 10 days prior to harvest, the greater was the severity of tipburn. A similar but not significant trend was evident in the data from the Crumb plot.

DISCUSSION

The results of these studies indicate that water deficiency, as shown by high soil moisture tension, was the primary cause of tipburn. The results are in line with the observations of Galloway (1894), Stone and Smith (1900), Knott, Andersen and Sweet (1939) and Beattie (1940), but contrary to those of Newhall (1929), Thompson (1926), Schwalen and Wharton (1930), Schmidt (1930, 1931), and Rawlins and McClain (1925). Low

soil temperatures increased tipburn. This was probably a result of further decreasing the availability of the soil moisture. Bouyoucos (1915) found that the ability of soils to hold water against the force of gravity increased as temperature was decreased from 50° C to 0° C. Kramer (1934) concluded "... lowering the temperature of the soil directly decreases the absorption of water in two ways: First, by its physical effects (chiefly increased viscosity and decreased vapor pressure), which result in a slower movement of water from soil to root; and second, by its physiological effects on the permeability of the root cells. Soil temperature also affects root growth and hence the size of the absorbing system, and thus indirectly the amount of absorption." Schroeder (1937, 1939) and Raleigh (1941) found that low temperatures decreased the intake of water by cucumber and melon plants, respectively.

There was a highly significant correlation in these experiments between severity of tipburn and the difference between maximum air and maximum soil temperature. Tipburn was most severe when this difference was the greatest. For any given difference between air and soil temperature, tipburn would be most severe when the soil temperature was lowest, unless both air and soil temperature were so low that water loss from the plant would be low. The greatest difference between air and soil temperature occurs when a cool, moist period is followed by a sunny, dry period. Newhall (1929) and others have noted that tipburn is most severe under just such conditions. It is believed that under such conditions water intake is too low to replace water loss and that the resulting water deficiency results in tipburn.

The results of Schmidt, (1930, 1931), are essentially in agreement with those reported here. An interesting relationship in his 1926 results was that each of the days on which percentage tipburn increased markedly was preceded by at least one day when there was a large difference between maximum soil temperature and maximum air temperature. On the other hand, low percentage tipburn periods were usually preceded by days when there was a small difference between maximum air temperature and maximum soil temperature.

The possibility exists that tipburn results from some physiological disorder in the plant which accompanies a reduced moisture supply to succulent tissues rather than to the reduced moisture supply itself. If such is the case, tipburn might also be brought about by other environmental conditions which might account for the divergent views concerning its cause.

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Department of Agriculture

Washington, D. C.

April 1, 1900

Mr. J. B. ...

Dear Sir:

I have the honor to acknowledge the receipt of your letter of the 27th inst. in relation to the ...

Very respectfully,
[Signature]

*The
Agricultural Experiment Station
At Cornell University*

was established 58 years ago for the primary purpose of solving the scientific problems of New York State farmers. At present, the staff of the Station is devoting its time to some 450 projects. These cover research that is fundamental in nature, such as that on breeding and genetics, as well as practical research on immediate problems, as, for example, shortages in farm labor, equipment, and materials, and control of diseases and insect pests. This bulletin is a report on the results of one phase of research at the Station.

C. E. H. Gutermuth

Director of Research